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Muscle Volume Measurement for Intensive Care Unit Acquired weakness using Computed Tomography: A Pilot Study

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Abstract

Muscle volume measurement is important for ICUAW evaluation, which has been done using ultrasound and manual muscle testing. We compared the reliability of CT and other methods for muscle volume measurement. This observational study assessed 7 patients 40 years old or older who had been admitted to our ICU. Based on a pre-specified CT protocol, muscle volume was evaluated on admission day and at 10-14 days after admission. Results show that the femoral muscle volume decreased significantly by up to 20%. The ICC between two raters was 0.97. Psoas muscle volume decline did not correlate with the femoral muscle decline. Femoral muscle volume evaluation was reliable and objective. This method is useful to quantify the ICUAW severity. Our pilot study based on CT femoral muscle volume evaluation will facilitate further studies to prevent ICUAW. Results show that CT using femoral muscle volume measurement is a reliable means of ICUAW evaluation.

Keywords: Intensive care unit; Femoral muscle; Psoas muscle; Inter-rater reliability

Introduction

Marked cognitive and physical decline are known to occur in many patients who survive intensive care unit (ICU) treatment. So-called ICU-acquired weakness (ICUAW) is one example of such physical decline. The physiological mechanism for ICUAW is a combination of critical illness neuropathy and critical illness myopathy [1]. Recovery to baseline physical function from ICUAW requires up to two years. Actually, ICUAW affects not only in-hospital mortality but also long-term prognosis [2]. The ICUAW severity assessment is based on medical research council (MRC) scoring, which consists of multiple manual muscle testing (MMT). However, this test is only reliable in the few patients who are awake and who can follow commands [1,3]. Therefore earlier reports have generally presented lower inter-rater or intra-rater reliability of MRC scores [3].

Recently, ultrasound is used widely to quantify the femoral muscle volume and to assess femoral muscle quality [3,4]. One study found up to 17.7% decline of the rectus femoris cross-sectional area (CSA) after 10 days of treatment in the ICU [5]. The same study showed that this CSA decline was related closely to the muscle protein/deoxyribonucleic acid (DNA) ratio and muscle fiber CSA decline obtained by muscle biopsy [5]. Furthermore, ultrasound has been reported as a reliable test of muscle necrosis quantification with the high intraclass correlation coefficient (ICC) of 0.97 [6]. Nevertheless, few studies have examined the reliability of ultrasound for muscle volume quantification.

Although it presents risk of radiation exposure, computed tomography (CT) is the most useful and reliable imaging test to quantify each organ's volume, including muscle volume [7]. One study, after calculating the muscle volume of cancer patients using CT imaging, compared the results with those of the patients' respective prognoses [8].

Although most such studies have specifically examined femoral muscles or limited body trunk muscles such as psoas muscles, few reports have described assessment of the correlation between whole body or body trunk muscle volume and femoral muscle volume. Moreover, in many ICUs, CT imaging is applied multiple times during a patient's ICU stay. Considering these points, we hypothesized that more reliable muscle volume quantification can be realized using CT as a part of ICUAW evaluation. Furthermore, CT muscle evaluation is useful to compare the femoral muscle volume change with muscle volume changes in other body parts. This pilot study was conducted to evaluate these hypotheses.

Materials and Methods

This observational study was conducted at our hospital, where about 300 patients are admitted to the ICU annually. The study term started from July 2016. Patients admitted to our ICU who were 40 years old over older and who were expected to stay in the hospital more than 14 days were included after they had heard an explanation of the study plan and had provided written consent. Patients under 40 years old and women of childbearing age were excluded considering the potential effects of CT radiation exposure. Patients who were discharged after fewer than 14 days admission, who died within 14 days, who did not consent to the study, or who had undergone leg amputation were also excluded.

A CT imaging study was conducted at admission from shoulder level to knee level. Separate from this study purpose, a CT imaging examination from the shoulder level to the pelvic level was required as part of clinical investigation for almost all ICU patients. The same CT imaging protocol was obtained after 10–14 days after admission and was used as follow-up data. This follow-up CT was performed at

appropriate timing considering each patient's clinical course and the hospital's holidays.

The primary outcome was set as femoral muscle volume reduction of follow-up CT compared with admission CT. This femoral muscle volume was calculated and recorded by two raters who used a pre-specified protocol and who were blinded to the other rater's calculation results. Inter-rater reliability was calculated. The protocol consists of three phases. First, the slice between the level of the caudal edge of the pelvis and the level of the distal edge of the femur was identified. Second, the scrotum and genital soft tissues were excluded from images. Finally, the area of CT value between 0 to 100 and the integral were calculated.

The psoas muscle volume was calculated similarly by one rater. The protocol for the psoas muscle was between the head side of first lumbar vertebra and the caudal side of the fifth lumbar vertebra. Intra-abdominal organs were excluded. The area with CT value between 0 to 100 was calculated. All these procedures were conducted using software (Synapse Vincent; Fujifilm Inc.). Target case numbers were set as 7–10 based on the muscle volume decline value reported from earlier studies [5].

Averages and standard deviations of femoral muscle and the psoas muscle volume were calculated. Each muscle volume of the included patients' follow-up CT was compared with the value obtained by CT on admission using a paired t-test with significance inferred for $p<0.05$. Inter-rater reliability was evaluated using the calculated ICC. Statistical analyses were conducted using software (JMP Pro ver.11; SAS Inc.).

This study was approved by the Ethics Committee of Hitachi General Hospital. The study explanation form included details related to risks of CT radiation exposure. Consent forms were obtained from all included patients or their surrogates.

Results

Patients were collected by continuous sampling based on the inclusion criteria. Data were collected from seven Japanese patients who had been admitted for various conditions: sepsis to drug overdose. The patients were not in a severe condition, but they needed several days of bed treatment: their mean SOFA score was 4.7; the APACHE 2 score was 12.7. Table 1 presents each patient's muscle volume change as recorded by each rater.

The femoral muscle volume decreased from the baseline mean volume of 3733 ml (SD: 1303 ml) to the follow-up mean volume of 2976 ml (SD: 1088 ml) yielding a 20% significant decline ($p=0.001$, Figure 1). The inter-rater reliability was quite high, with ICC 0.96 ($p<0.001$). However, the psoas muscle mean volume was 128 ml (SD: 28 ml) at baseline and 114 ml (SD: 37 ml) at follow up. Although it exhibited a decreasing tendency, no significant decline was found: $p=0.07$ (Figure 1).

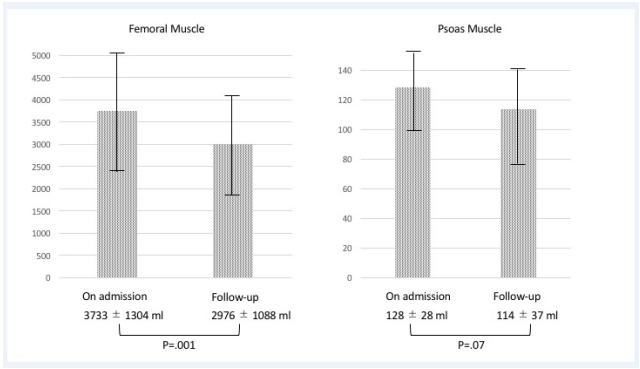

Figure 1: Average volume change of femoral and psoas muscles.

CT timing/Patient muscle part	On admission		Follow-up		Interval Days
	Rater 1 (ml)	Rater 2 (ml)	Rater 1 (ml)	Rater 2 (ml)	
1-Femoral	4360	4320	3320	3330	10
2-Femoral	3120	3170	2430	2460	12
3-Femoral	4570	4580	3730	3700	13
4-Femoral	2300	2290	1870	1850	11
5-Femoral	2000	2100	1900	1880	12
6-Femoral	4020	4080	2690	2730	14
7-Femoral	5610	5740	4850	4930	13
1-Psoas	153		154		10
2-Psoas	79		64		12
3-Psoas	141		136		13
4-Psoas	100		97		11

5-Psoas	126		73		12
6-Psoas	152		117		14
7-Psoas	146		155		13

Table 1: Patients' femoral and psoas muscle volume evaluated by two raters.

Discussion

This pilot study yielded reliable femoral muscle volume measurements obtained using CT for ICU patients. During 12.1 days after ICU admission, femoral muscle volume declined considerably, by about 20%, from the baseline value: that value was approximately equal to that described in reports of earlier studies [5]. Furthermore, considering the high inter-rater reliability, more accurate muscle volume evaluation was obtained than from ultrasound measurements. Although the tendency was evident, substantial absolute muscle volume variation between patients must be considered carefully during interpretation of the study results.

Regarding the psoas muscle, a slight but non-significant decreasing tendency was found, with marked variation of values among patients. The discrepancy of femoral and psoas muscle volume change suggests that the individual muscle volume did not reflect the whole-body muscle volume. Some attempt should be made to ascertain the best means of evaluating the functional muscle volume. Compared with whole-body muscle volume evaluation using whole-body CT [7], the femoral muscle volume itself should be emphasized from a functional perspective.

The CT-evaluated muscle volume measurement can be useful to evaluate ICUAW. This idea is supported further because multiple iterations of CT evaluation are necessary for clinically unstable ICU patients. The effects of CT radiation exposure on extremities are expected to be slight. Some earlier studies demonstrated that muscle volume is the strongest predictor of resting energy expenditure [9]. Considering this fact, the muscle volume and interventions to retain muscle volume are exceedingly important from a metabolic perspective to avoid future physical decline. Studies of muscle volume measurements combined with functional scoring such as MRC are necessary because muscle volume does not necessarily correlate with functional evaluation [3].

Several limitations might have affected this study. First, whether the pre-specified CT value truly corresponds to muscle volume was not verified. Second, because this study is a pilot study, few patients were examined. The heterogeneity of the included patients was considerable. Third, functional evaluation for ICUAW was not performed. Finally, no intervention to reduce the rate of muscle volume decline has been reported in the relevant literature.

Conclusion

Computed tomography using femoral muscle volume measurements can be a reliable component of ICUAW evaluation.

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